A model for Sustainability of abnormal profit
Linkage to quality function, positioning advantage, and purchasing pattern

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The objective of this paper is to develop a model to explain why some firms might gain abnormal profits for a long time in an industry.
According to this paper, characteristics of "Purchasing Pattern" and "Quality Improvement Function" can make an industry to be potentially capable of having sustainable high performers. In such industries, the difference in market position and start point might cause the difference in the capturing cost of a new source for market power which leads to variance in firm performance. In my example during this paper, a first mover firm which is a monopoly for a while can develop differentiated product and make it a new source of market power.

JEL classification: L13; L13; L25

Keywords: High Performance, Purchasing Pattern, Cost of Quality Improvement, Product Differentiation, Sustainable Competitive Advantage

1. Introduction[1]

During the past several years, empirical researchers in strategy field have tried to measure the relative importance of industry factors and firm factors to determine differences in firm performance (profitability). An earlier remarkable empirical research (Rumelt, 1991) shows that firm factors are accountable for the largest portion of the variance in firm performance (around 80%), and industry factors have much smaller effects (around 20%). Recently, some scholars, for example, Demsetz (1973) Page: 1
argued that the firm performance is mainly driven by firm factors and not by industry factors [Bowman and Constance, 2001]. This argument is contrary to the traditional framework to study Industrial Organization and Strategic Management, (Bain, 1956) and (Porter, 80), which assumed that industrial factors drive the difference in firm performance.

Recent critical researches (McGahan and Porter, 2003), (McGahan and Porter, 97), and (McGahan, 99) examine the sustainability of abnormal profits among a broad list of businesses between 1981 and 1994. Their results show strong asymmetries between high and low performers which can be summarized as:

- "High performance is more stable than low performance. High performers show profits above the average a decade earlier. In contrast, low performers show profits that are slightly above average a decade earlier." [McGahan and Porter, 2003]

[1] I would like to thank to Dr. Masoud Nili for many insightful comments and suggestions during my MBA's thesis. This paper has been written based on that thesis.

- Firm effects had more relative importance rather than industry effects in determining the variance of firm performance though industry effects had a large permanent component [McGahan, 1999].
- There are fewer firms above the average performance and more firms below the average performance i.e. the statistical median profit is less than the mean which leads us to conclude that there are a few firms with sustainable abnormal high profit. [Porter and McGahan, 97]

As McGahan stated: "The stylized facts suggest that competitive advantages—that is, differences between direct competitors in the same industry—were at least as important as industry influences on performance. Industry influences were more predictable and sustainable than competitive advantages, however" [McGahan, 1999].

According to empirical finding we can conclude that:

- High performers show a rather stable high profitability in the long run. It means there are few performers with abnormal high profit in the long run.
- Firm competitive advantage is accountable for most portion of high abnormal profit, though their competitive advantage can change over time from a special case to another.
- In some industries we can find a few high performers but in others the variance in firm performance is small i.e. High performers can be found only in some industries.

Although there is a rather rich literature on empirical research, there is little work in literature to develop an economic model to explain those empirical facts. The interesting question is "why do a few firms in some industries show sustainable abnormal performance while other competitors can not do so if we suppose there is no barrier to enter the industry?" In order to answer this question, we need to determine: 1) what characteristics of an industry make it potentially attractive to have room for high performers, 2) how a firm can be distinguished from others to be high performer, and 3) why other competitors can not beat the high performer.

These questions are the focus of the present paper to build up a model to explain sustainability of abnormal profits and the possibility of difference in firms' performances in the same industry. In addition to answering those questions, this paper tries to develop a model to show that a firm might gain abnormal profit for a long time in an industry even if there is no barrier for other firms to enter the market.

According to this paper, the following characteristics make an industry capable of having sustainable high performers:

- In consumer behavior side: "Purchasing Pattern[2]" of customers can be different from one industry to another and can change over time.

[2] For a detailed definition of "Purchasing Pattern" and its relation to "Consumer Preference and Choice Theory" refer to Appendix 1.

- In production function side: “Quality Improvement function” which we build its assumptions on the basis of “Learning By Doing” process and then, we extract the “cost function of quality improvement” from this quality improvement function.

Due to these characteristics of an industry and “different positions and start points” of firms in the industry, we show the possibility of sustainability of abnormal profit in the long run. In fact, different positions of firms in the market might cause differences in the cost of capturing a new source of market power, which lead to variance in firm performance.

The rationale behind this model is that the high performer tries to obtain a new source of market power based on its position in the market (for example, as a monopoly of the market for a short time). In my example during this paper, a first mover firm that is a monopoly for a while can develop differentiated product and make it a new source of market power.

2. Model

Suppose that there is a new product (basic product) introduced by Firm FM (first mover) and it has a monopoly power on it for a while (T=1). After that period, other producers may enter the market and the market for the basic product would be perfect competitive.

Increasing the quality of the basic product can vertically differentiate the product. The first mover firm might invest to improve the quality of the product in order to gain more during the monopolistic period and build up a market power by product differentiation for the period after the monopolistic period. After period T, another firm (second mover) might invest on quality in order to maximize profit. So, we assume a monopoly market for the first period (T<1) and an oligopoly market (for simplicity duopoly market) for the second period (T>1).

2.1 Assumptions:

I. There is no possibility of imitation for quality improvement. Each firm in the market faces the same expenditure function to improve the quality.

II. Total market size is constant (=1). Quality improvement has no effect on market size but it moves up Willingness-To-Pay function proportionally for all consumers in the market.

$\text{for } \forall q, u : w(q,u) = (1+u)w(q) \text{ st}: \; w'(q) < 0 \;\; \forall q > 0$

III. For simplicity suppose the production cost for the basic product is zero. So, after the monopolistic period the basic product’s price is zero. $MC = 0$

IV. Firms’ investment on quality improvement is constant over time. $\frac{\partial c}{\partial t} = cons.$

When we consider constant investment cost, in fact, we assume that the firm equipped a lab or department with some fixed amount of machinery and human resources in order to work on quality improvement.

V. Suppose quality cost ($\frac{\partial c}{\partial u}$) is a function of quality level (u) and quality speed ($\dot{u} = \frac{\partial u}{\partial t}$) and is an increasing function in both variables. $\frac{\partial c}{\partial u} = f(u, \dot{u})$ s.t.: $\frac{\partial f}{\partial u} > 0$ $\frac{\partial f}{\partial \dot{u}} > 0$. In this paper a simple form $\frac{\partial c}{\partial u} = au^a \dot{u}^b$ with $a, b > 0$ is used.

VI. There exists delay time between investment on quality and product's quality perception observed by customers. In this paper, delay period is assumed to be zero.

VII. We assumed perfect information in the market.

A two-period game with perfect information method (introduced by Prof. Sutton) is used to determine firms' decisions about investment expenditure on quality (long run variable) and price (short run variable).
In T<1 the market is monopolistic and in T>1 the market is duopolistic. For each firm in the market:

$$p_i = \int p_{it} q_{it} e^{-rt} dt - \int k_i e^{-rt} dt$$

Each firm should determine the amount of quality investment (ki) and the price level (pi) to maximize profit.

2.2. Extracting Demand Functions

We use the concept of willingness-to-pay and purchasing pattern to extract the demand function for each firm in the market[3]. We use the consumer discrete choice theory to find a way to explain demands of differentiated products in one industry.
We consider two simple purchasing patterns[4]: **Quality-based Purchasing Pattern** and **Value-based Purchasing Pattern**. We also assume that each customer in this market would purchase one and only one product[5].

Quality-Based Purchasing Pattern: in this pattern customers want to buy a product with the highest quality if they are willing to pay for its price (w(u)>p(u)).
Consider a market with n differentiated product and a basic product such that

[3] For a detailed description refer to appendix 1
[4] Purchasing pattern depends on the nature of the market. Technology possibilities to improve quality of products and its flavor for customer make the difference between industries. For example, for some industries with high rate of product development and innovation, it seems that the customer is more eager to buy new product with the highest feature and quality but technology possibilities restrict them to current products.
[5] Her willingness-to-pay for basic product is more than basic product's price which we assumed to be zero.

$u_1 > u_2 > ... > u_n > 0$.

Consumer decides to buy a product of this market. She would first consider the value[6] of product with the highest quality $(V_1 = W_1 - P_1)$ if its value is positive then she would buy the product with the highest quality. If not, she would consider the next product with highest quality and do so. If no one's value is positive, she would buy the basic product (witch we assumed zero priced).

Proposition 1: for an industry if assumption (II) is satisfied, $\text{for } \forall q, u : w(q,u) = (1+u)w(q) \text{ st}: \ w'(q) < 0 \ \ \forall q > 0$, and if the Purchasing Pattern is Quality-Based with n differentiated product, The first firm[7] maximizes its profit like a monopoly of the market (s1) because any customer which w(u)>p(u), would buy the first firm's product independent of other products' prices and qualities. The second firm behaves like a monopoly for the remaining customers, and so on.

For a market with linear willingness-to-pay function, the market shares would be ½, 1 / 4, 1 / 8,...

For the first firm:

$$p_1 = 1 + u_1 - (1+u_1)q_1 = (1+u_1)(1-q_1)$$

$$p_1 = p_1 q_1 \Rightarrow \frac{\partial p_1}{\partial p_1} = 0 \Rightarrow \begin{cases} s_1 = D_1 = 1/2 \\ p_1 = \frac{1}{2}(1+u_1) \\ p_1 q_1 = \frac{1}{4}(1+u_1) \end{cases}$$

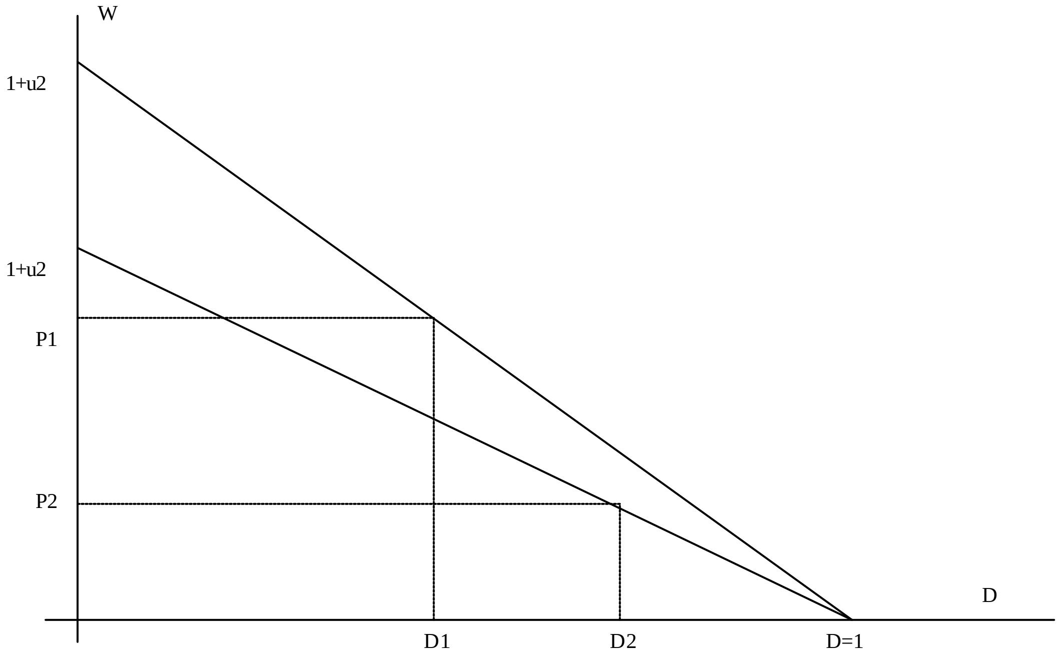
and for the second firm:

$$p_2 = \frac{1}{2}(1+u_2) - (1+u_2)q_2 = (1+u_2)(\frac{1}{2} - q_2)$$

$$p_2 = p_2 q_2 \Rightarrow \frac{\partial p_2}{\partial p_2} = 0 \Rightarrow \begin{cases} s_2 = D_2 - D_1 = 1/4 \\ p_2 = \frac{1}{4}(1+u_2) \\ p_2 q_2 = \frac{1}{16}(1+u_2) \end{cases}$$

[6] Value of a product for a customer is amount of willingness-to-pay minus price of the product.

[7] Firm with the highest quality



For a market with quadratic form of willingness-to-pay function:

$$p_1 = 1 + u_1 - (1 + u_1) q_1^2 = (1 + u_1)(1 - q_1^2)$$

$$p_1 = p_1 q_1 \Rightarrow \frac{\partial p_1}{\partial p_1} = 0 \Rightarrow \begin{cases} s_1 = D_1 = \sqrt{\frac{1}{3}} \\ p_1 = (1 - (\sqrt{\frac{1}{3}})^2)(1 + u_1) \\ p_1 q_1 = (1 - \frac{1}{3})\frac{1}{3}(1 + u_1) \end{cases}$$

Some results for a Quality-Based market:

- Market structure (firm size distribution) is defined by willingness-to-pay function and it's independent of quality levels.
- Price of a product is determined by its quality level and doesn't depend on other products quality level.
- The market structure is like a monopoly firm which can discriminate the consumer by introducing n type of a product.
- The firm with higher utility gains much more income than lower product for an additional improvement on quality level. So, it makes more incentive for the higher quality firm to invest on quality improvement.

Value-Based Purchasing Pattern: in this pattern, customers want to buy a product which maximizes her surplus value ($v(u) = w(u) - p(u)$).

Proposition 2: Suppose n differentiated products in the market ($u_1 > u_2 > ... > u_n > 0$) with prices $p_1 > p_2 > ... > p_n > 0$ and suppose assumption ii holds. If Purchasing Pattern is Value-Based, demands of firms can be extracted with following procedure:

Customers compare v_1 and v_j for j=2…n, if $v_1 > v_j$ all j then she would buy product 1. If $v_1 < v_2 > v_j$ for j=3…n, she would buy product 2 and so on. Therefore, customers between q=0 to the point that $w_1(q) - p_1(q) = w_2(q) - p_2(q)$ are the first firm's demand. Customers between $w_1(q) - p_1(q) = w_2(q) - p_2(q)$ and $w_2(q) - p_2(q) = w_3(q) - p_3(q)$ are the second firm's demand and so on.

Proof:

According to assumption ii, willingness-to-pay function is increasing in quality (u) and decreasing in q. $\text{for } \forall q, u : w(q,u) = (1+u)w(q) \text{ st} : w'(q) < 0 \ \forall q > 0$ so for firms i, and j (i>j):

$$v_i - v_j = w(q,u_i) - w(q,u_j) + p_i - p_j$$

$$\frac{\partial}{\partial q}(v_i - v_j) = (u_i - u_j)w'(q) < 0$$

Therefore, we can apply the procedure described above.

For linear willingness-to-pay function, demand functions of first firm and second firm would be:

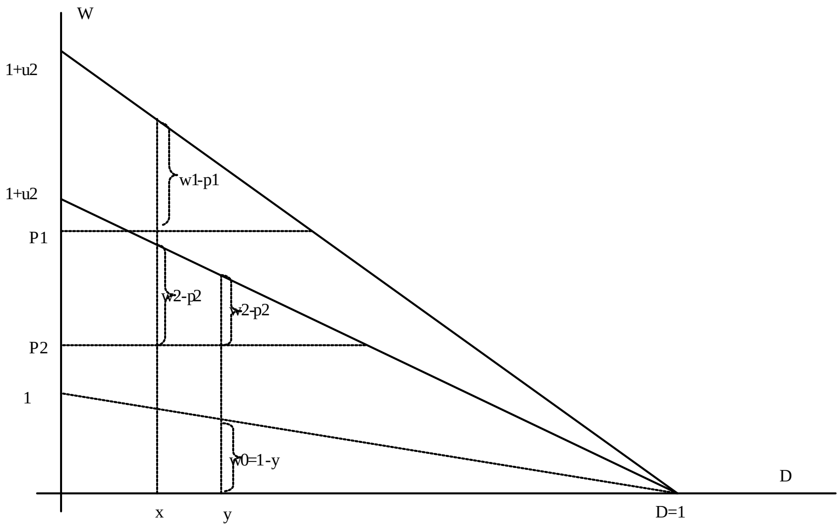
$$w_1 - p_1 = w_2 - p_2 \Rightarrow (1+u_1)(1-x) - p_1 = (1+u_2)(1-x) - p_2 \Rightarrow x = 1 - \frac{p_1 - p_2}{u_1 - u_2}$$

$$w_2 - p_2 = w_3 - 0 \Rightarrow (1+u_2)(1-y) - p_2 = 1 - y \Rightarrow y = 1 - \frac{p_2}{u_2} \Rightarrow x - y = \frac{p_1 u_2 - p_2 u_1}{u_2(u_1 - u_2)}$$

$$D_1 = 1 - \frac{p_1 - p_2}{u_1 - u_2} \quad D_2 = \frac{p_1 u_2 - p_2 u_1}{u_2(u_1 - u_2)}$$

As we see, demands of both firms depend on both p1 and p2. So, profits of the firms depend on price levels of all firms and $\frac{\partial p_i}{\partial p_j} \langle 0$, $\frac{\partial p_2}{\partial p_1} = \frac{p_2}{u_1 - u_2}$ $\frac{\partial p_1}{\partial p_2} = \frac{p_1}{u_1 - u_2}$.

Therefore, if p1>p2 then profit sensitiveness of first firm with respect to changes in second firm's price is more than second firm's profit with respect to firs firm's price.



In comparison to the Quality-Based Purchasing Pattern, it's clear that first mover's demand and price is more close to the second mover's. Therefore:

Proposition 3: In comparison to the Quality-Based PP, when PP is Value-Based: 1) the first mover's profit is more close to the second mover's 2) the profits of the firms converge to each other rapidly 3) second mover has more incentive to invest on quality improvement in order to attract some customers of first mover.

2.3. Extracting Quality Cost Function

Suppose quality cost ($\frac{\partial c}{\partial u}$) is a function of utility level (u) and quality speed ($\dot{u} = \frac{\partial u}{\partial t}$) and is increasing function in both variables.

$$\frac{\partial c}{\partial u} = f(u, \dot{u}) \text{ s.t.: } \frac{\partial f}{\partial u} > 0 \quad \frac{\partial f}{\partial \dot{u}} > 0 .$$

The reason is that for the higher quality level, more complicated and more expensive methods are required to improve the quality. We suppose that there exists some kind of "learning by doing" during quality improvement period (lab work, scientific work, operation work, marketing work … which cause quality improvement is incremental). So, the higher speed in quality improvement, the lower possibility of learning and more money required.

Proposition 3: If the quality expenditures over time is constant ($\frac{\partial c}{\partial t}=k$)[8] and condition 1 for quality cost function is satisfied then quality is increasing and concave in variables time (t) and constant quality cost (k). It means for u=g(t,k) we have

$$\begin{cases}\frac{\partial u}{\partial k}>0\\ \frac{\partial^2 u}{\partial k^2}<0\end{cases}\qquad \begin{cases}\frac{\partial u}{\partial t}>0\\ \frac{\partial^2 u}{\partial t^2}<0\end{cases}$$

Proof:

Proposition 4: For special case $\frac{\partial c}{\partial u}=au^a\dot{u}^b$ with $a,b>0$ we have $u=a'k^g t^l$ st.: $0<g,l<1$

Proof:

$$\left.\begin{aligned}\frac{\partial c}{\partial t}&=k\\ \frac{\partial c}{\partial u}&=au^a\dot{u}^b\end{aligned}\right| \Rightarrow ku^{-a}=\dot{u}^{b+1}\Rightarrow \dot{u}=(\frac{k}{a}u^{-a})^{\frac{1}{b+1}}\Rightarrow \frac{\partial u}{\partial t}=(\frac{k}{a})^{\frac{1}{b+1}}u^{-\frac{a}{b+1}}\Rightarrow u^{\frac{a}{b+1}}du=(\frac{k}{a})^{\frac{1}{b+1}}dt$$

$$\frac{u^{\frac{a}{b+1}+1}}{\frac{a}{b+1}+1}=t\times(\frac{k}{a})^{\frac{1}{b+1}}\Rightarrow u=(\frac{a+b+1}{b+1})^{\frac{b+1}{a+b+1}}\times(\frac{1}{a})^{\frac{1}{a+b+1}}\times k^{\frac{1}{a+b+1}}\times t^{\frac{b+1}{a+b+1}}$$

With following change of variables:

$$\left.\begin{aligned}(\frac{a+b+1}{b+1})^{\frac{b+1}{a+b+1}}\times(\frac{1}{a})^{\frac{1}{a+b+1}}&=a'\\ \frac{1}{a+b+1}&=g\\ \frac{b+1}{a+b+1}&=l\end{aligned}\right\}\Rightarrow u=a'k^g t^l \quad 0<g,l<1$$

[8] when we consider constant investment cost, in fact we assume that the firm equipped a lab or department with some fixed amount of machinery and human resources in purpose of working on quality improvement.

3.1 Short-Run Equilibrium (Firms' decisions on price)

According to assumption IV and III, ki is constant and production costs of basic product are zero. So, given long-run variable (ki), each firm determine prices to maximize $p_i = p_i q_i$

We solve the model for linear willingness-to-pay function:

Monopoly period (T<1):

$$p_1 = 1 + u_0 - (1 + u_0) q_0 = (1 + u_0)(1 - q_0)$$

$$p_0 = p_0 q_0 \Rightarrow \frac{\partial p_0}{\partial p_0} = 0 \Rightarrow \begin{cases} s_0 = D_0 = 1/2 \\ p_0 = \frac{1}{2}(1 + u_0) \\ p_0 q_0 = \frac{1}{4}(1 + u_0) \end{cases}$$

<u>Duopoly period (T>1) and Quality-Based purchasing Pattern:</u>

for first mover:

$$p_1 = 1 + u_1 - (1 + u_1) q_1 = (1 + u_1)(1 - q_1)$$

$$p_1 = p_1 q_1 \Rightarrow \frac{\partial p_1}{\partial p_1} = 0 \Rightarrow \begin{cases} s_1 = D_1 = 1/2 \\ p_1 = \frac{1}{2}(1 + u_1) \\ p_1 q_1 = \frac{1}{4}(1 + u_1) \end{cases}$$

for second mover:

$$p_2 = \frac{1}{2}(1 + u_2) - (1 + u_2) q_2 = (1 + u_2)(\frac{1}{2} - q_2)$$

$$p_2 = p_2 q_2 \Rightarrow \frac{\partial p_2}{\partial p_2} = 0 \Rightarrow \begin{cases} s_2 = D_2 - D_1 = 1/4 \\ p_2 = \frac{1}{4}(1 + u_2) \\ p_2 q_2 = \frac{1}{16}(1 + u_2) \end{cases}$$

<u>Duopoly period (T>1) and Value-Based purchasing Pattern:</u>

Demand functions:

$$w_1 - p_1 = w_2 - p_2 \Rightarrow (1+u_1)(1-x) - p_1 = (1+u_2)(1-x) - p_2 \Rightarrow x = 1 - \frac{p_1 - p_2}{u_1 - u_2}$$

$$w_2 - p_2 = w_3 - 0 \Rightarrow (1+u_2)(1-y) - p_2 = 1 - y \Rightarrow y = 1 - \frac{p_2}{u_2} \Rightarrow x - y = \frac{p_1 u_2 - p_2 u_1}{u_2(u_1 - u_2)}$$

$$D_1 = 1 - \frac{p_1 - p_2}{u_1 - u_2} \quad D_2 = \frac{p_1 u_2 - p_2 u_1}{u_2(u_1 - u_2)}$$

Reaction functions:

$$p_1^* = p_1^*(p_2) \wedge \frac{\partial p_1}{\partial p_1} = 0 \Rightarrow 1 - \frac{2p_1 - p_2}{u_1 - u_2} = 0 \Rightarrow 2p_1 - p_2 = u_1 - u_2 \Rightarrow p_1^* = \frac{u_1 - u_2}{2} + \frac{p_2}{2}$$

$$p_2^* = p_2 * (p_1) \wedge \frac{\partial p_2}{\partial p_2} = 0 \Rightarrow \frac{p_1 u_2 - 2p_2 u_1}{u_2(u_1 - u_2)} = 0 \Rightarrow p_1 u_2 - 2p_2 u_1 = 0 \Rightarrow p_2 * = \frac{u_2}{2u_1} p_1$$

-Nash equilibrium:

$$p_1^* = p_2^* \Rightarrow p_2^* = \frac{u_2}{2u_1}\left(\frac{u_1 - u_2}{2} + \frac{p_2^*}{2}\right) \Rightarrow \begin{cases} p_2^* = \frac{u_2(u_1 - u_2)}{4u_1 - u_2} \\ p_1^* = 2\frac{u_1(u_1 - u_2)}{4u_1 - u_2} \end{cases}$$

$$D_1 = 1 - \frac{p_1 - p_2}{u_1 - u_2} \quad D_2 = \frac{p_1 u_2 - p_2 u_1}{u_2(u_1 - u_2)}$$

$$p_1 = p_1 D_1 = \left(1 - \frac{2\frac{u_1(u_1 - u_2)}{4u_1 - u_2} - \frac{u_2(u_1 - u_2)}{4u_1 - u_2}}{u_1 - u_2}\right) 2\frac{u_1(u_1 - u_2)}{4u_1 - u_2} = (u_1 - u_2)\left[\frac{2u_1}{4u_1 - u_2}\right]^2$$

$$p_2 = p_2 D_2 = \frac{u_2(u_1 - u_2)}{4u_1 - u_2} \frac{2\frac{u_1(u_1 - u_2)}{4u_1 - u_2} u_2 - \frac{u_2(u_1 - u_2)}{4u_1 - u_2} u_1}{u_2(u_1 - u_2)} = u_1 u_2 (u_1 - u_2)$$

-Stackelberg equilibrium (firs mover leader, second mover follower)

$$p_2 * = \frac{u_2}{2u_1} p_1 \Rightarrow p_1 = D_1 \ p_1 = \left(1 - \frac{p_1 - \frac{u_2}{2u_1} p_1}{u_1 - u_2}\right) p_1 = \left(1 - \frac{2u_1 - u_2}{2u_1(u_1 - u_2)} p_1\right) p_1$$

$$\Rightarrow \frac{\partial p_1}{\partial p_1} = 0 \Rightarrow 1 - \frac{2u_1 - u_2}{u_1(u_1 - u_2)} p_1 = 0 \Rightarrow u_1(u_1 - u_2) = (2u_1 - u_2) p_1 \Rightarrow p_1{*} = \frac{u_1(u_1 - u_2)}{2u_1 - u_2}$$

$$\Rightarrow p_2{*} = \frac{u_2}{2u_1} \times \frac{u_1(u_1 - u_2)}{2u_1 - u_2} \Rightarrow p_2{*} = \frac{u_2(u_1 - u_2)}{2(2u_1 - u_2)}$$

$$p_1^{*} = \frac{1}{2} p_1 = \frac{u_1(u_1 - u_2)}{2(2u_1 - u_2)}$$

$$p_2^{*} = D_2 p_2 = \frac{\frac{u_1(u_1 - u_2)}{2u_1 - u_2} u_2 - \frac{u_2(u_1 - u_2)}{2(2u_1 - u_2)} u_1}{u_2(u_1 - u_2)} \frac{u_2(u_1 - u_2)}{2(2u_1 - u_2)} = u_1 u_2 (u_1 - u_2)$$

-stackelberg equilibrium (second mover leader, first mover follower)

$$p_1^{*} = \frac{u_1 - u_2}{2} + \frac{p_2}{2}$$

$$p_2 = p_2 q_2 = \frac{(\frac{u_1 - u_2}{2} + \frac{p_2}{2}) u_2 - p_2 u_1}{u_2(u_1 - u_2)} p_2$$

$$\frac{\partial p_2}{\partial p_2} = 0 \Rightarrow \frac{u_1 - u_2}{2} + p_2 u_1 - 2 p_2 u_1 = 0 \Rightarrow p_2{*} = \frac{u_1 - u_2}{2(2u_1 - u_2)}$$

$$\Rightarrow p_1{*} = \frac{u_1 - u_2}{2} + \frac{u_1 - u_2}{4(2u_1 - u_2)} \Rightarrow p_1{*} = \frac{(u_1 - u_2)(5u_1 - 3u_2)}{4(2u_1 - u_2)}$$

Based on these calculations the second equilibrium is the best for both firms and it's likely to accept it as the competition pattern in the market.

3.2 Long-Run Equilibrium (Firms' decision on quality investment)

Profit of first mover in monopoly period:

$$p_0 = \int_0^T p_{0t} q_{0t} e^{-rt} dt - \int_0^T k_0 e^{-rt} dt$$

profits in duopoly period:

$$p_1 = \int_T^\infty p_{1t} q_{1t} e^{-rt} dt - \int_T^\infty k_1 e^{-rt} dt$$

$$p_2 = \int_T^\infty p_{2t} q_{21t} e^{-rt} dt - \int_T^\infty k_2 e^{-rt} dt$$

<u>Duopoly period (T>1) and Quality-Based purchasing Pattern:</u>

$$p_F = p_0 + p_1$$

$$p_F = \int_0^\infty \frac{1}{4} (1 + u_{1t}) e^{-rt} dt - \int_0^\infty k_F e^{-rt} dt$$

$$p_F = \int_0^\infty \frac{1}{4} (1 + a' k_F{}^g t^l) e^{-rt} dt - \int_0^\infty k_F e^{-rt} dt$$

$$\frac{\partial p_F}{\partial k_F} = 0 \Rightarrow \int_0^\infty \frac{1}{4} a' g k_F^{\;g-1} t^l e^{-rt} dt - \int_0^\infty e^{-rt} dt = 0$$

$$k_F^{\;g-1} = \frac{\int_0^\infty e^{-rt} dt}{\frac{1}{4} a' g \int_0^\infty t^l e^{-rt} dt} \Rightarrow k_F = \left[\frac{\int_0^\infty e^{-rt} dt}{\frac{1}{4} a' g \int_0^\infty t^l e^{-rt} dt} \right]^{\frac{1}{g-1}}$$

$$p_L = \int_T^\infty \frac{1}{16}(1+u_{2t}) e^{-rt} dt - \int_T^\infty k_L e^{-rt} dt$$

$$p_L = \int_0^\infty \frac{1}{16}(1+u_{2t}) e^{-r(t+T)} dt - \int_0^\infty k_L e^{-r(t+T)} dt$$

$$p_L = \int_0^\infty \frac{1}{16}(1+a' k_L^{\;g} t^l) e^{-r(t+T)} dt - \int_0^\infty k_L e^{-r(t+T)} dt$$

$$\frac{\partial p_L}{\partial k_L} = 0 \Rightarrow \int_0^\infty \frac{1}{16} a' g k_L^{\;g-1} t^l e^{-r(t+T)} dt - \int_0^\infty e^{-r(t+T)} dt = 0$$

$$k_L^{\;g-1} = \frac{e^T \int_0^\infty e^{-rt} dt}{\frac{1}{16} e^T a' g \int_0^\infty t^l e^{-rt} dt} \Rightarrow k_L = (4)^{\frac{1}{g-1}} \times \left[\frac{\int_0^\infty e^{-rt} dt}{\frac{1}{4} a' g \int_0^\infty t^l e^{-rt} dt} \right]^{\frac{1}{g-1}}$$

$$k_L = (4)^{\frac{1}{g-1}} \times k_F \quad 0 < g < 1 \Rightarrow 0 < (4)^{\frac{1}{g-1}} < 1/4$$

$$\Rightarrow k_L < k_F / 4$$

It means First Mover spends more money on quality improvement and its quality is more than second mover forever but its quality (and profit) would be converge to the second mover because the quality function is increasing and concave in k (quality expenditure). So we can inference:

Proposition 5: Under some assumptions (I, II, III, IV, V, VI) and with linear willingness-to-pay function (for simplicity), If the purchasing pattern is Quality-Based then 1) first mover's investment on quality improvement (k) is the highest among all firms in the market. 2) Forever, first mover's profit is higher than others in the market but eventually they converge.

But in real world, after some while it might be seen that first mover's profit converges or even becomes less than others in the market. Main reasons might be: 1) quality cost function is concave. So, eventually qualities of the products converge to each other 2) and much more likely, after some significant advance in technology and quality improvement, customers change their pattern from Quality-Based to Value-Based. 3) Quality improvement and product innovation is a random process in its nature, so it's likely that other firms make a breakthrough or great advance in product innovation. In fact, we only considered deterministic process of quality improvement incrementally and we ignored probability process of innovation and breakthrough inventions. 4) In real world assumption VI (Zero delay and perfect information) is violated, it can change the game structure and our propositions.

As we saw, first mover developed new source of market power and competitive advantage (better quality) based on its position on the market which make its profit be higher than others for some while even after previous advantage (being monopoly and first mover). We can say that it can be repeated more ever. Fore example to prevent reducing profit, first mover can build up a royal brand, de-facto standard, or other new source of advantage based on its advantage in the market.

Appendix 1: Purchasing Pattern and Consumer Choice

When customer q goes to market, she would buy a product which her willingness-to-pay for that product is more than its price W(q,u)>P(u) but there might be several differentiated products in one industry with that condition. The main question is "How does a customer evaluate different products and choose a product when she faces several differentiated products in the market?"

Actually, we try to find out the customer q's rational preference relation $\overset{q}{\succsim}$ among members of a set of products with different qualities and prices (all differentiated products in this market and the basic product).

Definition 1: "**Purchasing Pattern**" is a rational preference relation of consumer q $\overset{q}{\succsim}$ over set of differentiated products X:

$$X = \{x_1, x_2, ..., x_n, x_0\} : x_i = (u_i, p_i) \text{ for all } i = 0,..,n$$

where $x_i = (u_i, p_i)$is a differentiated product with u_i quality and p_i price,

and x_o is the basic product. for simplicity assume $x_0 = (0,0)$

Based on rationality definition [Mas-collel, Whinston, and Green, 95] $\overset{q}{\succsim}$ is rational iif

(i) *completeness* :for all $x, y \in X$ we have that $x \succsim y$ or $y \succsim x$

(ii) *transivity*: for all $x, y, z \in X$, if $x \succsim y$ and $y \succsim z$ then $x \succsim z$

Quality can affect customers differently and so it might be troublesome to find the appropriate relation. So, we try to find a way to convert quality to a measurable function which is different for all customers.

We define a function called willingness-to-pay for the basic product witch assigned a real number for customer q and it determine how much she is willing to pay to buy the basic product W(q). If we sort all customers in the market[9] from the highest amount of willingness-to-pay to the lowest, w(q) would be a decreasing function ($w'(q) < 0$ f $for all q \in [0,1]$). For differentiated products define willingness-to-pay function as following:

Definition 2: **"willingness-to-pay of customer q for the basic product of an industry** $w(q)$ **"** is the maximum price of the basic product which customer q would prefer to buy the product when her choice set is to buy the product or save the money (no buying from the industry) and **"willingness-to-pay for a differentiated product"** is the maximum price of that product which customer q would prefer to buy the product when her choice set is to buy the differentiated product or save the money (no buying from the industry)

Definition 3: "**Quality Value Function**" is a function $v(q,u)$ such that:

$v(q,u) = w(q,u) / w(q)\ st:$

customers of the market is sorted based on their willingness-to-pay for the basic product.

$w(q) = w(q,0)$ is the willingness-to-pay of the customer q for the basic product (u=0) ($w'(q) < 0$).

$w(q,u)$ is the willingness-to-pay of the customer q for the differentiated product with quality u.

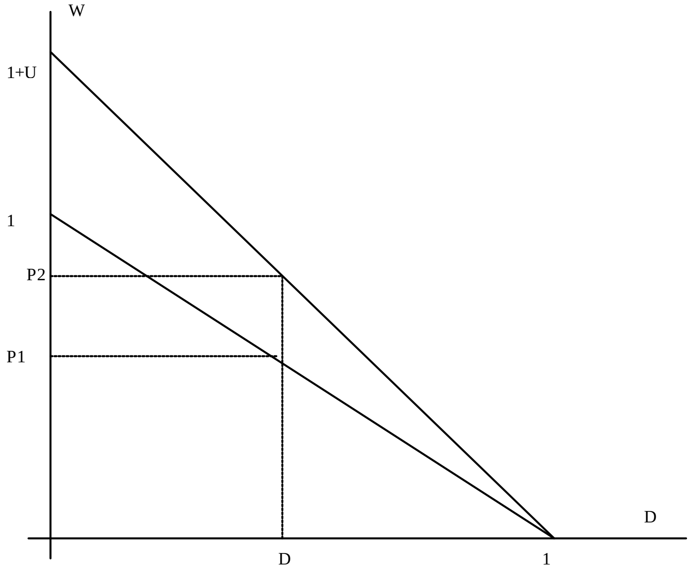
We assume that quality value is a decreasing function

i.e: $for all q,u\ \frac{dv}{dq} \geq 0\ and\ \frac{dv}{du} > 0$

Figure 1 shows the effect of quality improvement on willingness-to-pay and market size. For the sake of simplicity, assume unitary market size and linear willingness-to-pay function w(q,u=0)= 1-q. Quality improvement has no effect on market size but it moves up Willingness-To-Pay function proportionally for all consumers in the market. $for\ \forall q,u : w(q,u) = (1+u)w(q)\ st:\ w'(q) < 0\ \ \forall q > 0$

Willingness-to-pay of customer q for the basic product (u=0) is w(q,u=0)= 1-q and for a product with quality U=u, her willingness-to-pay is w(q,u)= (1+u)(1-q). It means quality improvement doesn't increase total market size while proportionally increases willingness-to-pay of each person for that product.

[9] Supposing unitary market size



So, based on this new function we can convert original problem to the following problem:

Find out the customer q's rational preference relation $\overset{q}{\succeq}$ among members of a set of products (all differentiated products in this market and the basic product) with different willingness-to-pay and prices.

Definition 4: "**Purchasing Pattern**" is a rational preference relation of consumer q $\overset{q}{\succeq}$ over set of differentiated products X:

$$X = \{x_1, x_2, ..., x_n, x_0\} : x_i = (w_i, p_i) \text{ for all } i = 0,..,n$$

where $x_i = (w_i, p_i)$ is a differentiated product with u_i quality and p_i price, and x_o is the basic product. for simplicity assume $x_0 = (0,0)$

Which Willingness-to-pay of a product is defined by Definition 2.

In this paper we assume customer q would select one and only one x_i over set X. An easier way to show "Purchasing Pattern" is using Choice Structure which is equivalent to find rational preference relation.

Definition 5: "Purchasing Pattern" is a Choice Structure $(2^b, C_q(.))$ such that:

$(i)\ 2^b$ *is the set of all subsets of* $b = \{x_1,..., x_n, x_0\}$ where

$x_i = (w_i, p_i)$ for all $i = 0,.., n$ represents i-th differentiated products

which p_i is its price and $w_i(u_i,q)$ is its willingness-to-pay function.

x_0 is the basic product.

$(ii)\ C_q(.)$ *is choice rule*:

for any h *subset of* b, $C_q(h) \in h$ *is the customer q's unique choice among members of* h

(iii) *Choice Structure satisfies weak axiom of revealed preference*

Because we defined that one and only one member has been assigned by choice rule so, the relationship between first problem (rational preference) and second problem (choice structure) is as following:

for any choice structure (defined as above) exists a rational relation $(\overset{q}{\succsim})$ *such that*

$$x \overset{q}{\succsim} y \Leftrightarrow (x = C_q(h)\ \text{for any}\ h \subset b\ \text{and}\ x, y \in h)$$

So, in this paper we try to find choice rules ($C_q(.)$). In this paper, to find choice rule of customer q, we consider two simple purchasing patterns: **Quality-based Purchasing Pattern** and **Value-based Purchasing Pattern**.

"Purchasing Pattern" depends on the nature of the market. Technology possibilities to improve quality of products and the quality value for customer make the difference between industries. For example, for some industries with high rate of product development and innovation, it seems that customer is more eager to buy new product with the highest feature and quality but technology possibilities restrict them to current products.

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